Manufacturing & Prototyping

Glass Solder Approach for Robust, Low-Loss, Fiber-to-Waveguide Coupling

Goddard Space Flight Center, Greenbelt, Maryland

The key advantages of this approach include the fact that the index of interface glass (such as Pb glass n = 1.66) greatly reduces Fresnel losses at the fiber-to-waveguide interface, resulting in lower optical losses. A contiguous structure cannot be misaligned and readily lends itself for use on aircraft or space operation. The epoxy-free, fiber-to-waveguide interface provides an optically pure, sealed interface for low-loss, high-power coupling. Proof of concept of this approach has included successful attachment of the low-melting-temperature glass to the x–y plane of the crystal, successful attachment of the low-melting-temperature glass to the end face of a standard SMF (single-mode fiber), and successful attachment of a wetted low-melting-temperature glass SMF to the end face of a KTP crystal.

There are many photonic components on the market whose performance and robustness could benefit from this coupling approach once fully developed. It can be used in a variety of fiber-coupled waveguide-based components, such as frequency conversion modules, and amplitude and phase modulators. A robust, epoxy-free, contiguous optical interface lends itself to components that require low-loss, high-optical-power handling capability, and good performance in adverse environments such as flight or space operation.

This work was done by Shirley McNeil, Philip Battle, and Todd Hawthorne of AdvR, Inc.; and John Lower, Robert Wiley, and Brett Clark of 3SAE Technologies, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16348-1

Lightweight Metal Matrix Composite Segmented for Manufacturing High-Precision Mirrors

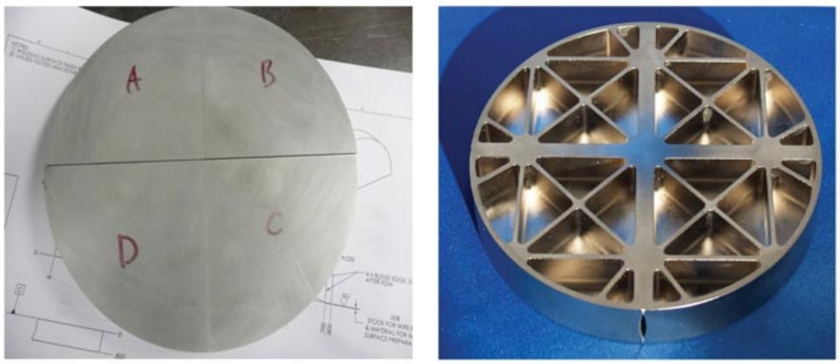
New approach is examined to reduce production costs.

Goddard Space Flight Center, Greenbelt, Maryland

High-precision mirrors for space applications are traditionally manufactured from one piece of material, such as lightweight glass "sandwich" or beryllium. The purpose of this project was to develop and test the feasibility of a manufacturing process capable of producing mirrors out of welded segments of AlBeMet® (AM162H). AlBeMet® is a HIP'd (hot isostatic pressed) material containing approximately 62% beryllium and 38% aluminum. As a result, AlBeMet® shares many of the benefits of both of those materials for use in high performance mirrors, while minimizing many of their weaknesses.

AlBeMet® machines more like aluminum than beryllium, but retains many of the beneficial structural characteristics of beryllium, such as a lower coefficient of thermal expansion (CTE), greater stiffness, and lower density than aluminum. AlBeMet® also has as a key characteristic that it can be electron-beam welded, and AlBeMet® has been demonstrated as a suitable material for use as an optical substrate. These last two characteristics were central to the selection of AlBeMet® as the material to be used in the construction of the segmented mirror. In order to effectively compare the performance of the monolithic and the segmented mirror, a plano mirror was designed.

A plano mirror is the best design, as it minimizes the effect of extraneous factors on the performance of the final mirror, such as the skill of the polisher to achieve the proper prescription. A plano mirror will also theoretically retain the same prescription when segmented and then reassembled. Any material lost to the kerf will not change the prescription, unlike, for example, a spherical mirror whose radius of curvature will become smaller with the loss of material. The mirror design also incorporates light-weighting cavities and stiffening ribs, as is typical in space-based mirror



Front of the welded mirror substrate. **Back** of the finished mirror.

design. Thicker ribs were required along the proposed cutting/welding lines to facilitate the machining of those surfaces when the mirror was segmented. The mirror was designed to be cut into four (4) equal segments. As a result, the thicker ribs ran perpendicular to each other through the center of the mirror.

The monolithic mirror was machined and ground by closely following Materion's suggested fabrication process for AlBeMet®, including stabilization, temperature cycling, and in-process inspection checks. Once the flatness had been obtained, the mirror was sent for nickel plating. The mirror was plated with high-phosphorous nickel to a thickness between 0.003 and 0.004 in. (≈0.076 and 0.102 mm) in accordance with specification AMS 2404, class I. After nickel-plating, the mirror was stabilized and then polished to obtain a finished optic. In the end, the monolithic mirror achieved a surface figure of nearly ¼ λ (0.286 λ) at 633 nm with a surface roughness of 15 Å rms.

The monolithic mirror was then prepared to be segmented and welded. The nickel-plating on the mirror had to be completely stripped off in order to facilitate welding. The mirror was cut into four quarters using a wire EDM process. The segments were stabilized and cleaned before being delivered to Materion for the welding process. The welds along the mirror surface were done first and the mirror flipped and aligned, and the backside, along the bottom of the ribs, was welded.

Following welding, one first had to remove enough material from the mirror surface to get below any surface damage or other irregularities caused by the weld. A small amount of material was also removed from the backside of the mirror, simply to clean up the appearance of that weld. The mirror was stress relieved before being ground to the proper flatness requirement, after which the mirror was inspected and sent out for nickel plating.

The returned mirror underwent the grinding and polishing process in the same manner as that used on the monolithic mirror. The mirror was ground and polished until it achieved a surface figure of less than 1 (at 633 nm), temperature cycled for stabilization, and then remeasured. In the end, the segmented mirror achieved a surface figure of less than 0.7 at 633 nm with a surface roughness measured at 16.5 Å. It is very probable that a better surface figure could have been achieved on the segmented mirror, but budget constraints of this Phase I project prevented further efforts.

Based on the results presented, the feasibility of creating high-performance mirrors out of welded segments of AlBeMet® has been proven and has the potential for being used in a full-size astronomical mirror.

This work was done by Vladimir Vudler of Hardric Laboratories, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16165-1

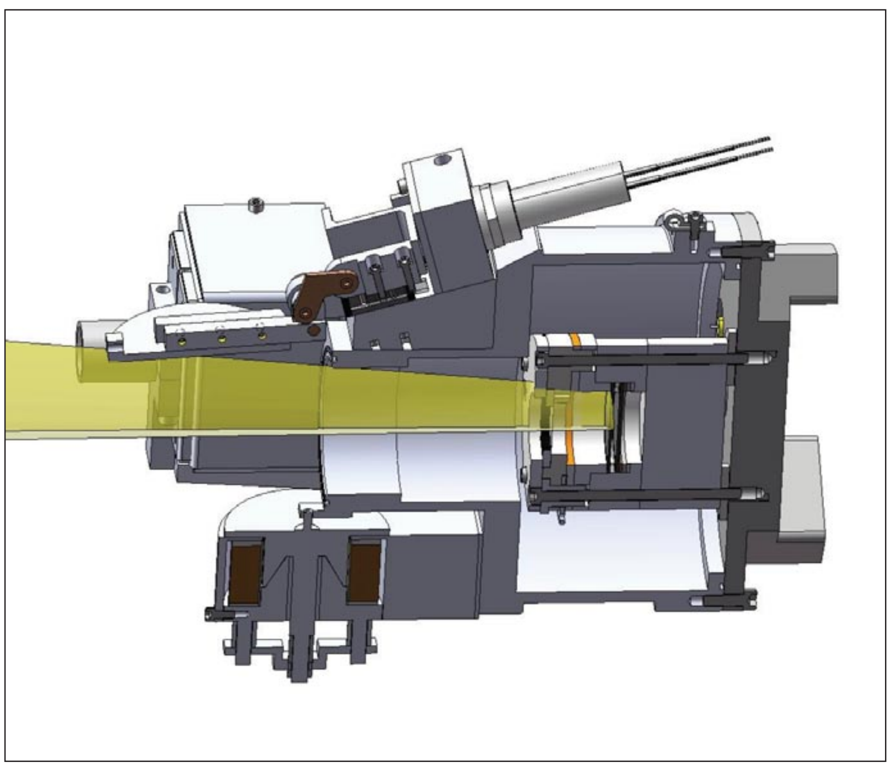
Plasma Treatment To Remove Carbon From Indium UV Filters

Hydrogen plasma cleaning is used in sterilization applications in healthcare as an alternative to autoclaving.

NASA's Jet Propulsion Laboratory, Pasadena, California

The sounding rocket experiment FIRE (Far-ultraviolet Imaging Rocket Experiment) will improve the science community's ability to image a spectral region hitherto unexplored astronomically. The imaging band of FIRE (≈900 to 1,100 Å) will help fill the current wavelength imaging observation hole existing from ≈620 Å to the GALEX band near 1,350 Å. FIRE is a single-optic prime focus telescope with a 1.75-m focal length. The bandpass of 900 to 1100 Å is set by a combination of the mirror coating, the indium filter in front of the detector, and the salt coating on the front of the detector's microchannel plates. Critical to this is the indium filter that must reduce the flux from Lyman-alpha at 1,216 Å by a minimum factor of 10^{-4}. The cost of this Lyman-alpha removal is that the filter is not fully transparent at the desired wavelengths of 900 to 1,100 Å.

Recently, in a project to improve the performance of optical and solar blind detectors, JPL developed a plasma process capable of removing carbon contamination from indium metal. In this work, a low-power, low-temperature



A cutaway view shows the **Detector Assembly and Filter**. The indium filter sits just in front of the detector plates in the light beam (yellow cone) at the orange ring.